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Plug-in Electric Vehicle (PEV) Readiness

7 May 2014

Alternative Clean Transportation (ACT) Expo 2014
Long Beach CA

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innovation.luskin.ucla.edu/ev

Outline

- Background: market status
  - PEVs products and charging levels
  - PEV and charging-station market penetration
- PEV readiness planning
  - Charging-station siting example: geographical demand and supply assessment of the South Bay
- Charging-station financial viability

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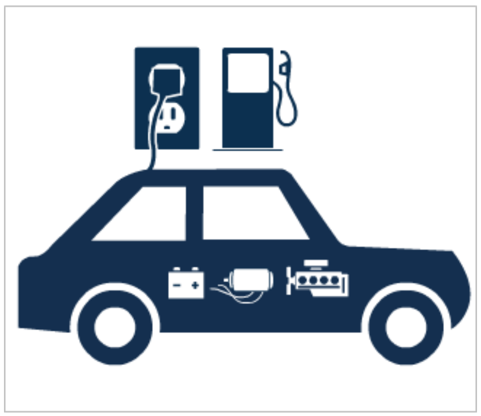
What is available?

Light-duty PEV products

“Electric Vehicles”

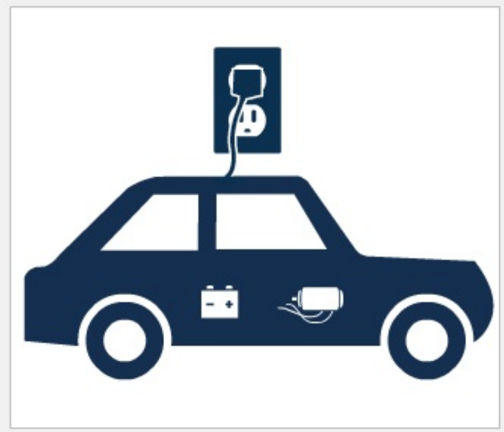
- **Plug-in** EVs (**PEVs**) —i.e., electric-fuel vehicles—comprise *both* **plug-in-hybrid EVs** and **all-battery EVs**
- Many common components under the hood, but different products for the consumer with distinct policy implications…

Plug-in-hybrid EVs (PHEVs)



Plug It in or Fill It Up
Plug-in hybrid electric vehicles have an internal combustion engine and electric motor. These vehicles are powered by an alternative fuel or a conventional fuel, such as gasoline, and a battery, which you can plug in to charge.

All-battery EVs (BEVs)



No More Gasoline
All-electric vehicles are plugged in to charge the battery, which stores the electricity that powers the electric motor.

http://www.afdc.energy.gov/vehicles/electric.html

Plug-in-hybrid EVs (1 of 3, in order of release)

bdw@ucla.edu	Vehicle	MSRP	Fuel economy* (gas–electric)	Range* (electric, total)
	GM Chevy Volt	\$34,185	37–98 mpg_e	38 e-mi 380 mi total
	Toyota Prius Plug-in	\$29,990	50–95 mpg_e	11 e-mi 540 mi total
	Ford C-Max Energi	\$32,950	43–100 mpg_e	21 e-mi 620 mi total
	Honda Accord Plug-in	\$39,780	46–115 mpg_e	13 e-mi 570 mi total
	Ford Fusion Energi	\$34,700	43–100 mpg_e	21 e-mi 620 mi total

*EPA rating

(photos and MSRPs from OEM websites 2/14)

Plug-in-hybrid EVs (2 of 3, in order of release)

bdw@ucla.edu	Vehicle	MSRP	Fuel economy (gas–electric)	Range (electric, total)
	Porsche Panamera S E-Hybrid	$99,000	~30–72 mpg$_e$	20 e-mi (NEDC) >220 mi total
	GM Cadillac ELR	$75,000	33–82 mpg$_e$*	37 e-mi* 340 total*
	Hyundai Sonata Plug-in Hybrid	TBD in 2014		
	Mitsubishi Outlander P-HEV	TBD in 2014		
	Mercedes S 500 Plug-in Hybrid	TBD in 2014		

*EPA rating

Plug-in-hybrid EVs (3 of 3, in order of release)

bdw@ucla.edu	Vehicle	MSRP	Fuel economy (gas–electric)	Range (electric, total)
	Volvo V60 PHEV	TBD in 2014		
	VW Golf twinDRIVE	TBD in 2014		
	Audi A4 e-quattro	TBD in 2014		
	Audi A3 e-tron	TBD in 2014		
	BMW i8	TBD in 2015		

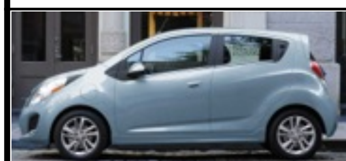
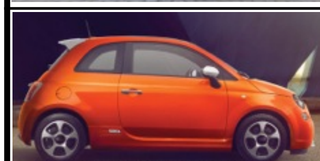
All-battery EVs (1 of 3, in order of release)

bdw@ucla.edu	Vehicle	MSRP	Fuel economy* (gas–electric)	Range* (electric, total)
	Nissan LEAF	$28,800	116 mpg_e	75 e-mi
	smart electric	$25,000	107 mpg_e	68 e-mi
	Mitsubishi i	$29,125	112 mpg_e	62 e-mi
	Ford Focus Electric	$35,170	105 mpg_e	76 e-mi
	Tesla Model S	$71,070	95 mpg_e	208 e-mi

*EPA rating

(photos and MSRPs from OEM websites 2/14)

All-battery EVs (2 of 3, in order of release)

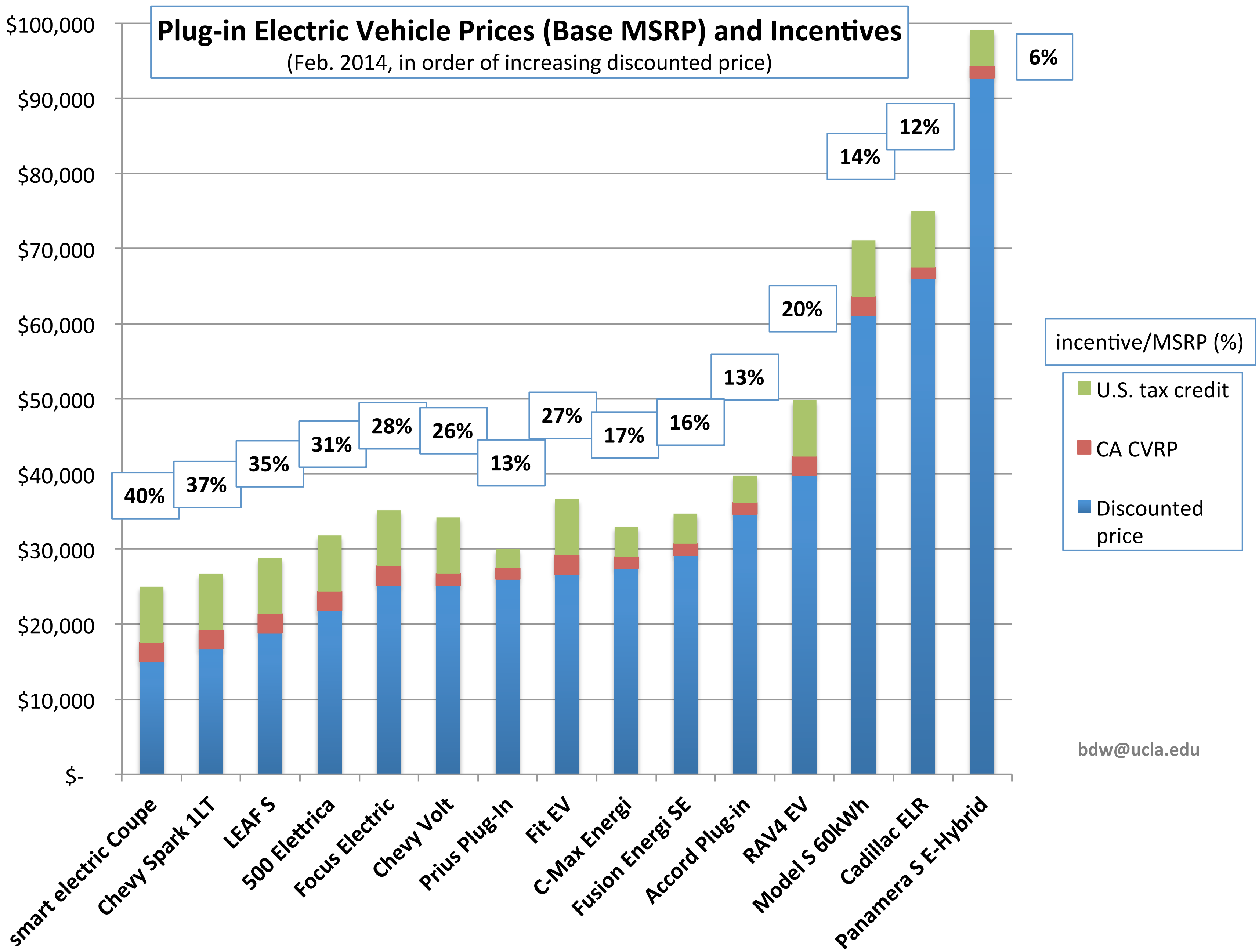
bdw@ucla.edu	Vehicle	MSRP	Fuel economy* (gas–electric)	Range* (electric, total)
	Honda Fit EV	$36,625	118 mpg_e	82 e-mi
	Toyota RAV4EV (Tesla inside)	$49,800	78 mpg_e	103 e-mi
	Chevy Spark EV	$26,685	118 mpg_e	82 e-mi
	Fiat 500e	$31,800	116 mpg_e	87 e-mi
	BMW i3	Soon		

*EPA rating

(photos and MSRPs from OEM websites 2/14)

All-battery EVs (3 of 3, in order of release)

bdw@ucla.edu	Vehicle	MSRP	Fuel economy (gas–electric)	Range (electric, total)
	Mercedes B-Class Electric	TBD in 2014		
	Tesla Model X	TBD in 2014		
	VW e-Golf	TBD in 2014		
	Kia Soul EV	TBD in 2014		
	Infinity LE	TBD in 2014		



Plug-in Electric Vehicle Prices (Base MSRP) and Incentives
(Feb. 2014, in order of increasing discounted price)
$100,000
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$-
40%
37%
35%
31%
28%
26%
13%
27%
17%
16%
13%
20%
14%
12%
6%
smart electric Coupe
Chevy Spark 1LT
LEAF S
500 Elettrica
Focus Electric
Chevy Volt
Prius Plug-In
Fit EV
C-Max Energi
Fusion Energi SE
Accord Plug-in
RAV4 EV
Model S 60kWh
Cadillac ELR
Panamera S E-Hybrid
incentive/MSRP (%)
U.S. tax credit
CA CVRP
Discounted price
bdw@ucla.edu

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How are they doing?

PEV and charging-station market penetration

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U.S. Plug-in Electric Vehicle Sales Trends & Analysis

Dec 2010 — Feb 2014

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18-Mar-14

http://luskin.ucla.edu/blogs/brettwilliams

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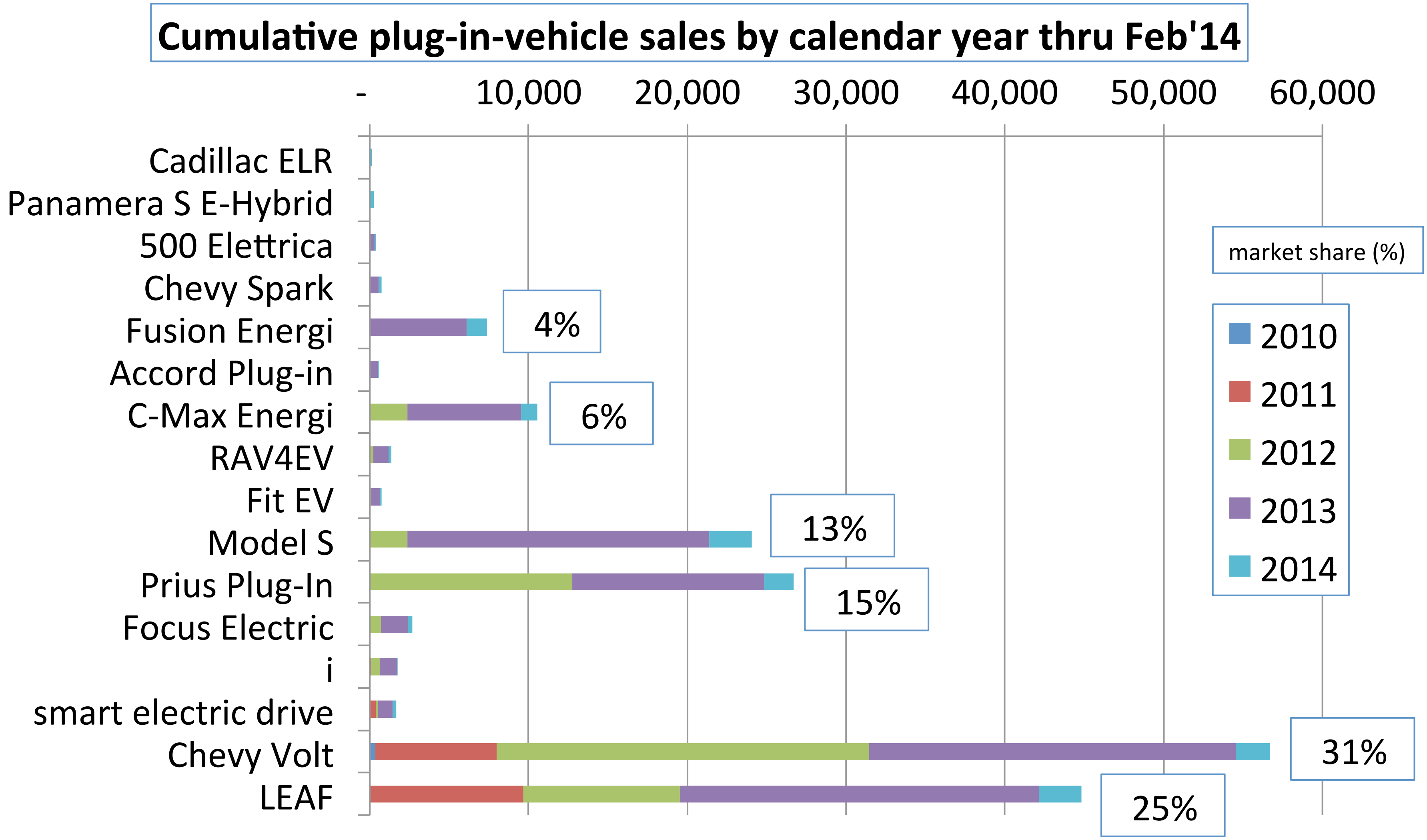
Where are we with plug-in electric vehicles (PEVs)?

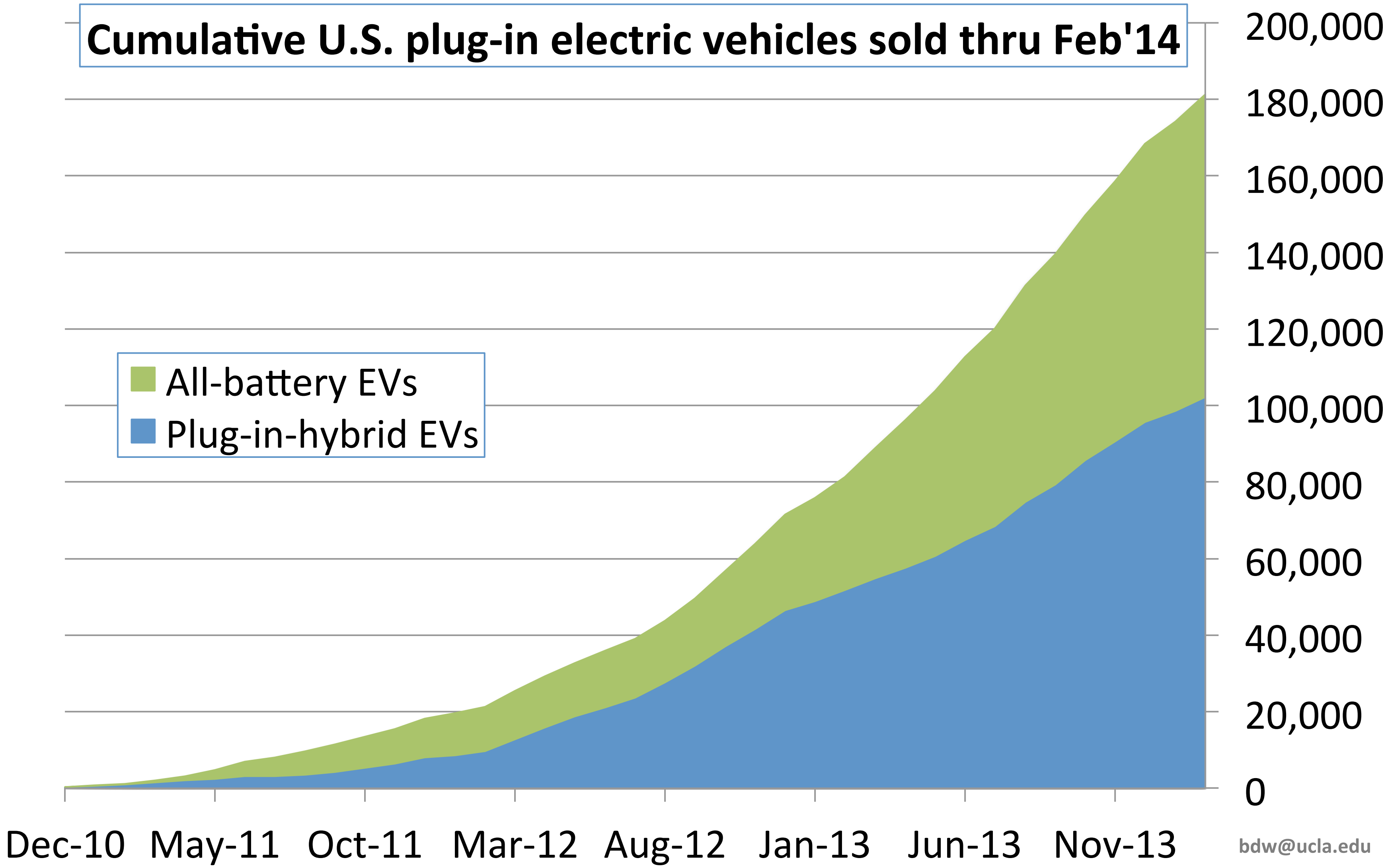
Cumulative U.S. light-duty sales

Light-duty U.S. PEVs sold and market share



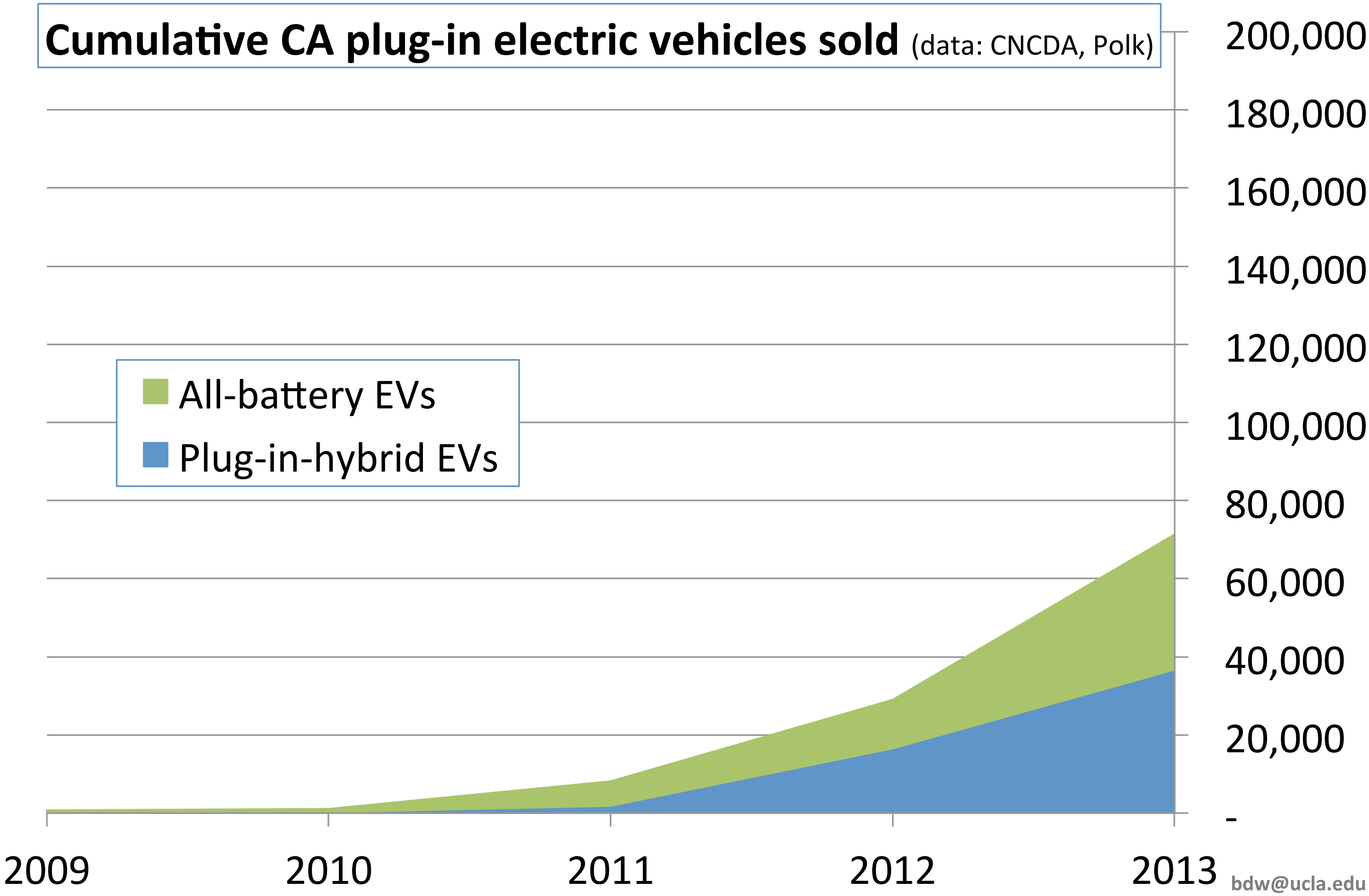
bdw@ucla.edu

by PEV type



Cumulative U.S. plug-in electric vehicles sold thru Feb'14
All-battery EVs
Plug-in-hybrid EVs
200,000
180,000
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
Dec-10
May-11
Oct-11
Mar-12
Aug-12
Jan-13
Jun-13
Nov-13
bdw@ucla.edu

by PEV type, CA



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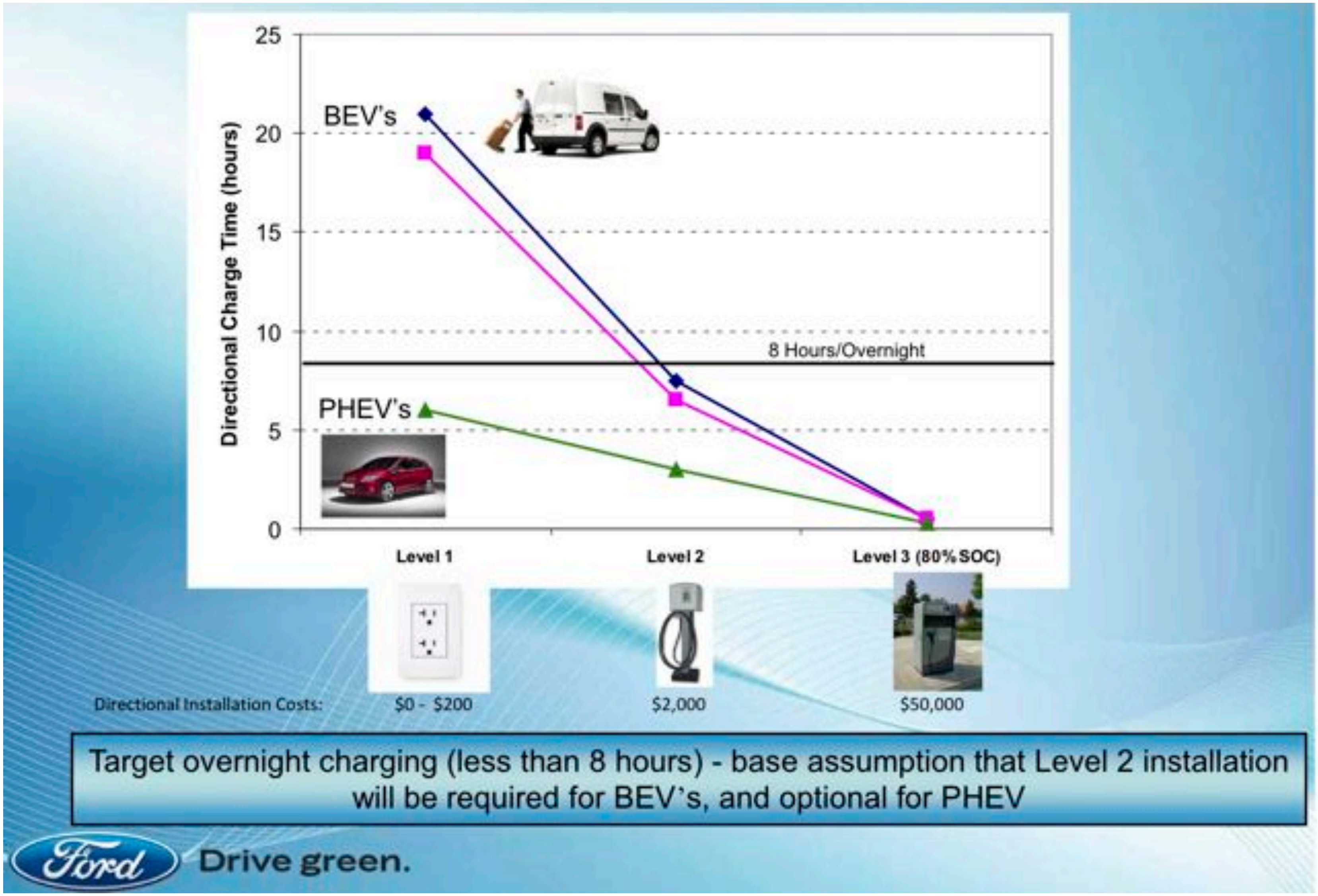
What kinds of stations are available?

e-infra by Level, Charge Time (Marakby 2010)



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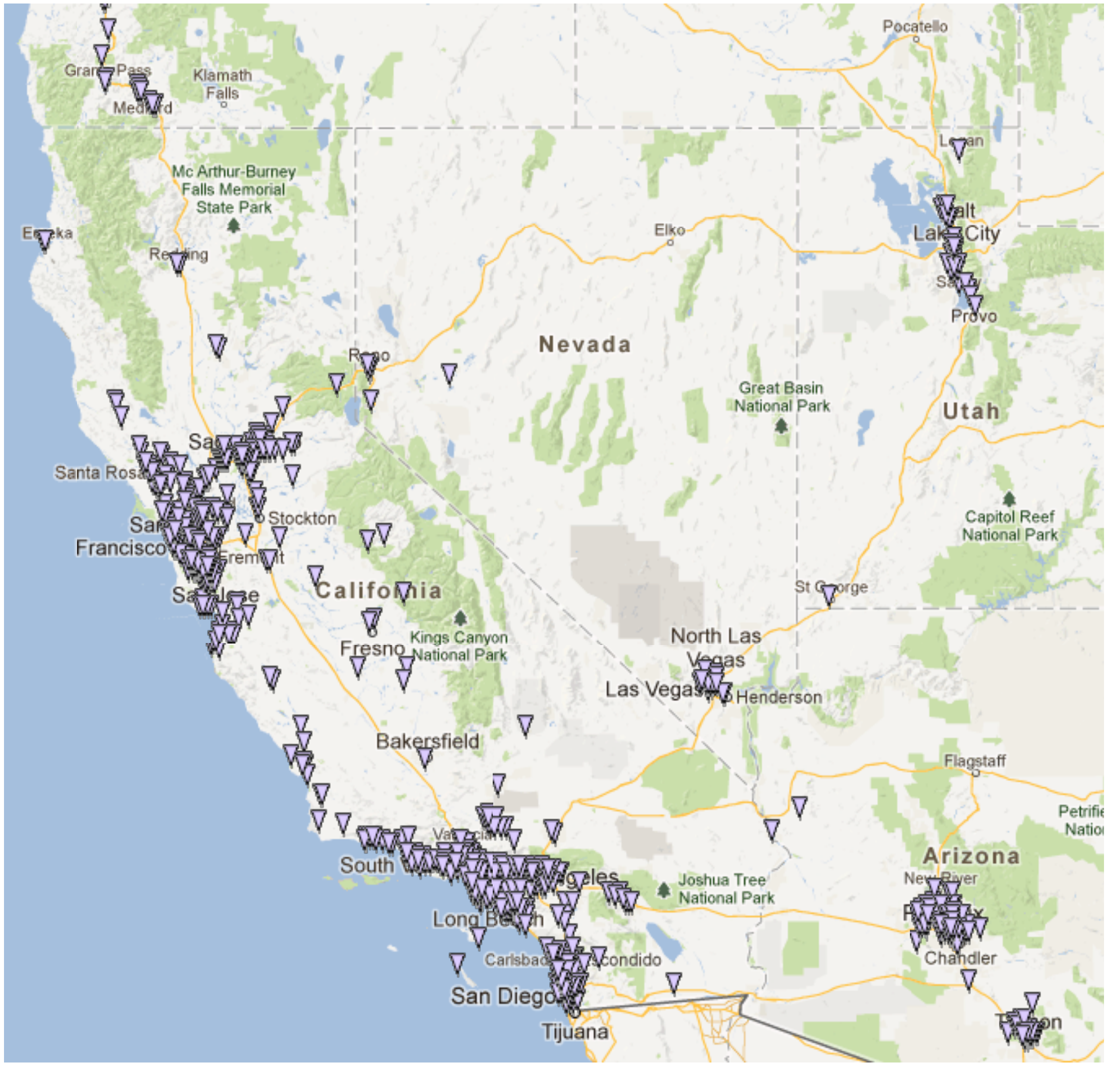
Where are we with refueling infrastructure?

Charging Stations

California charge stations (~1,626 as of Feb’14)



Alternative Fuel Stations - Electric

Existing Electric Stations

Planned Electric Stations

(produced Mar. 2014 using http://maps.nrel.gov/transatlas)

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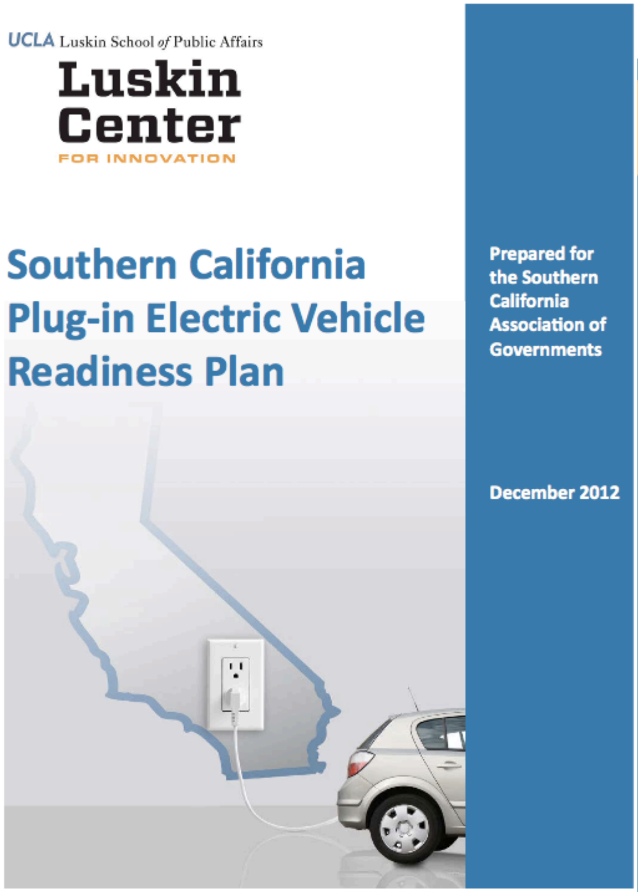
Regional PEV readiness planning

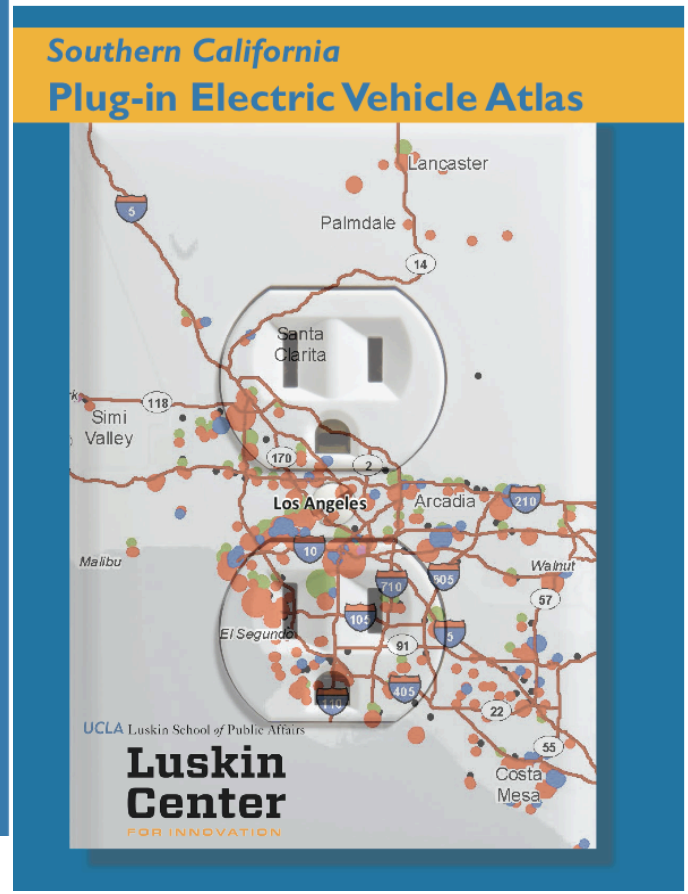
Particular thanks to:

Prof. JR DeShazo, Luskin Center Director

Ayala Ben-Yehuda, PEV Readiness Project Manager

Policies and planning guidance to facilitate charging installation and operation





Prioritize *locations* for charging

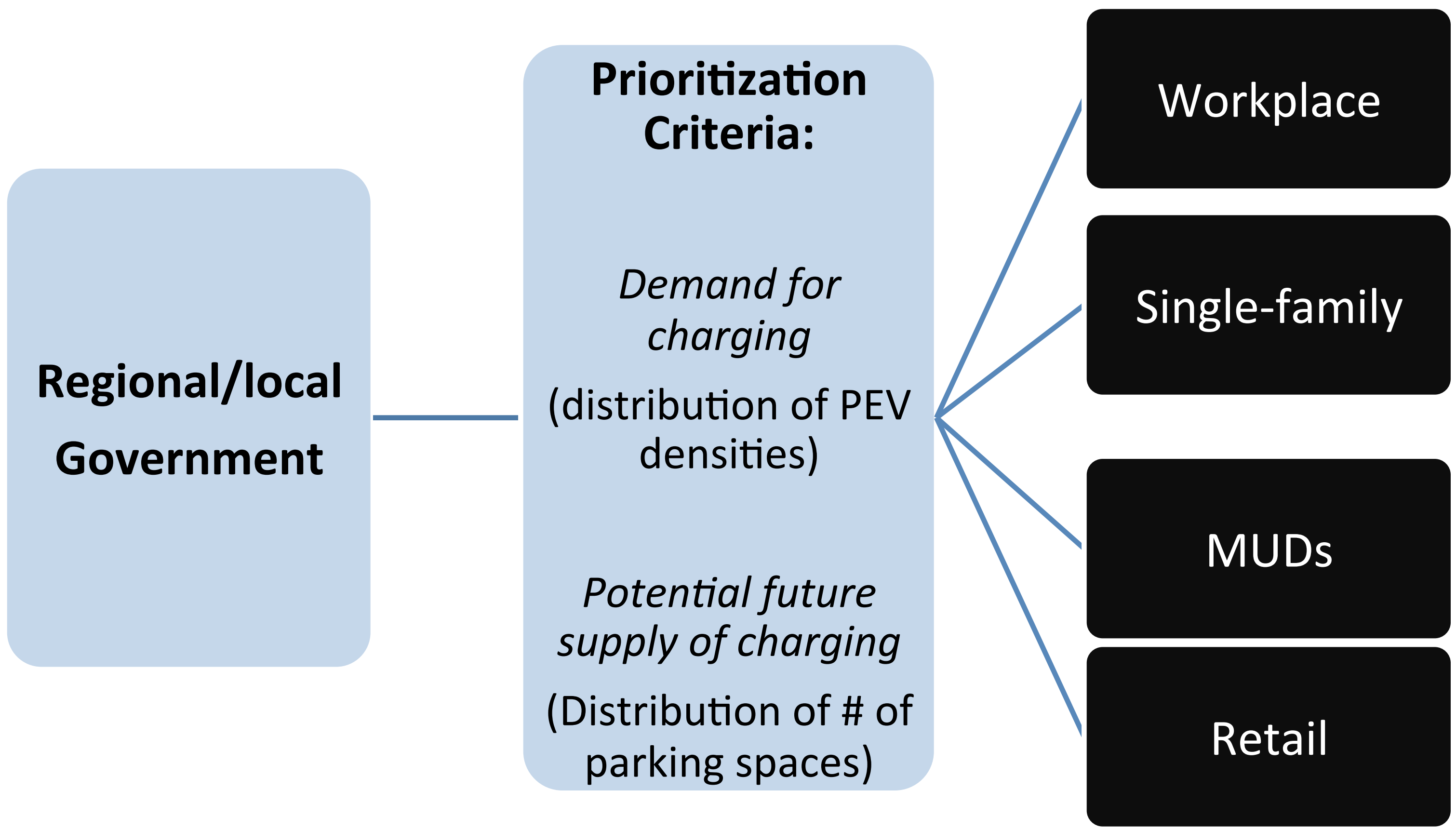
Southern California PEV Readiness Plan and Atlas

Download at innovation.luskin.ucla.edu/ev

Policy & Planning Guidance

- **Siting** and **pricing** charging stations
  - Multi-unit-dwelling, workplace, public-sector, commercial
- **Permitting** and **inspecting** installations
- Regulating **parking** and **signage**
  - Accessibility
- **Building** and **zoning codes**
  - Including PEV-ready wiring in new construction
- **Outreach**

Example: Sub-regional PEV Planning Process



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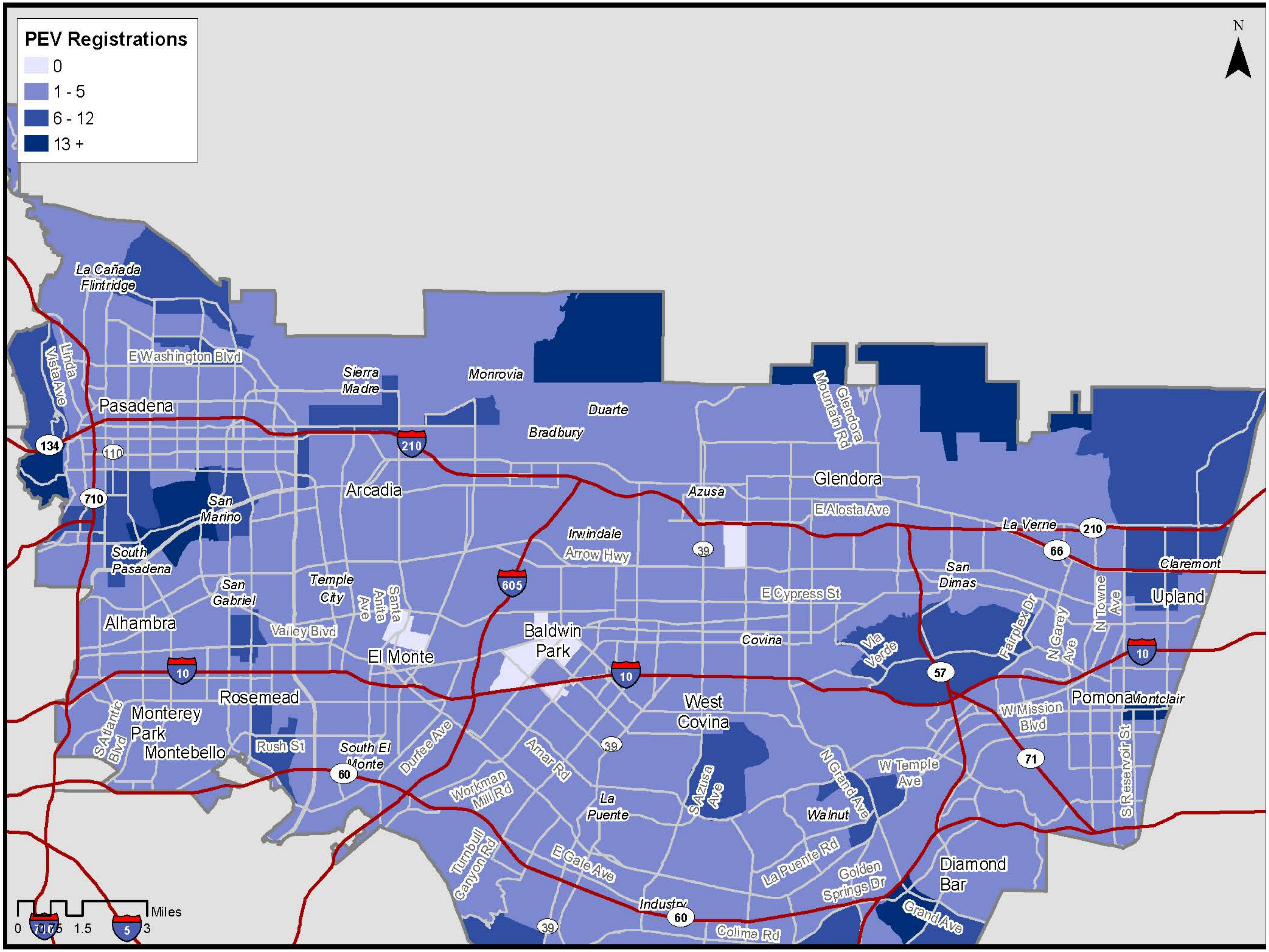
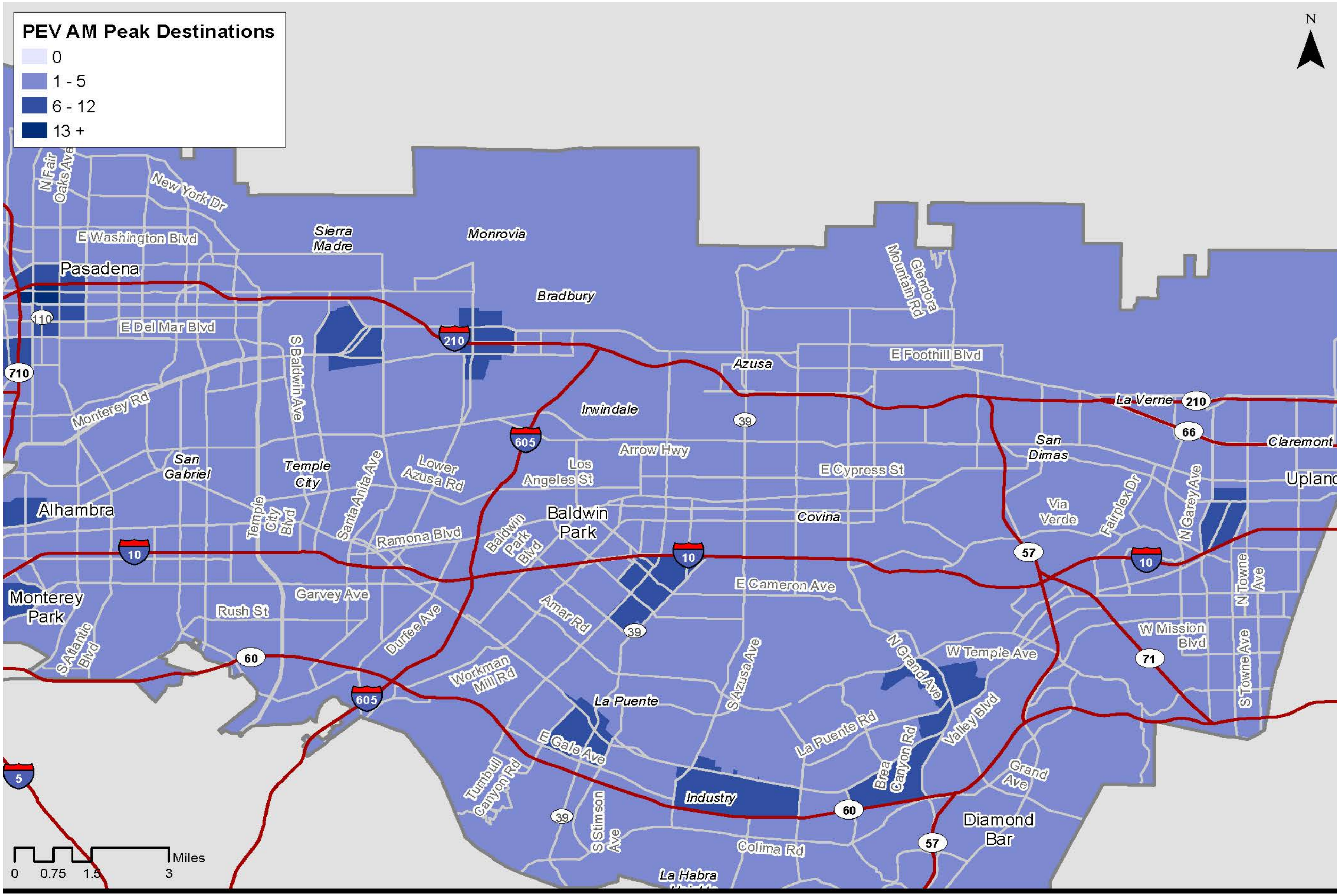
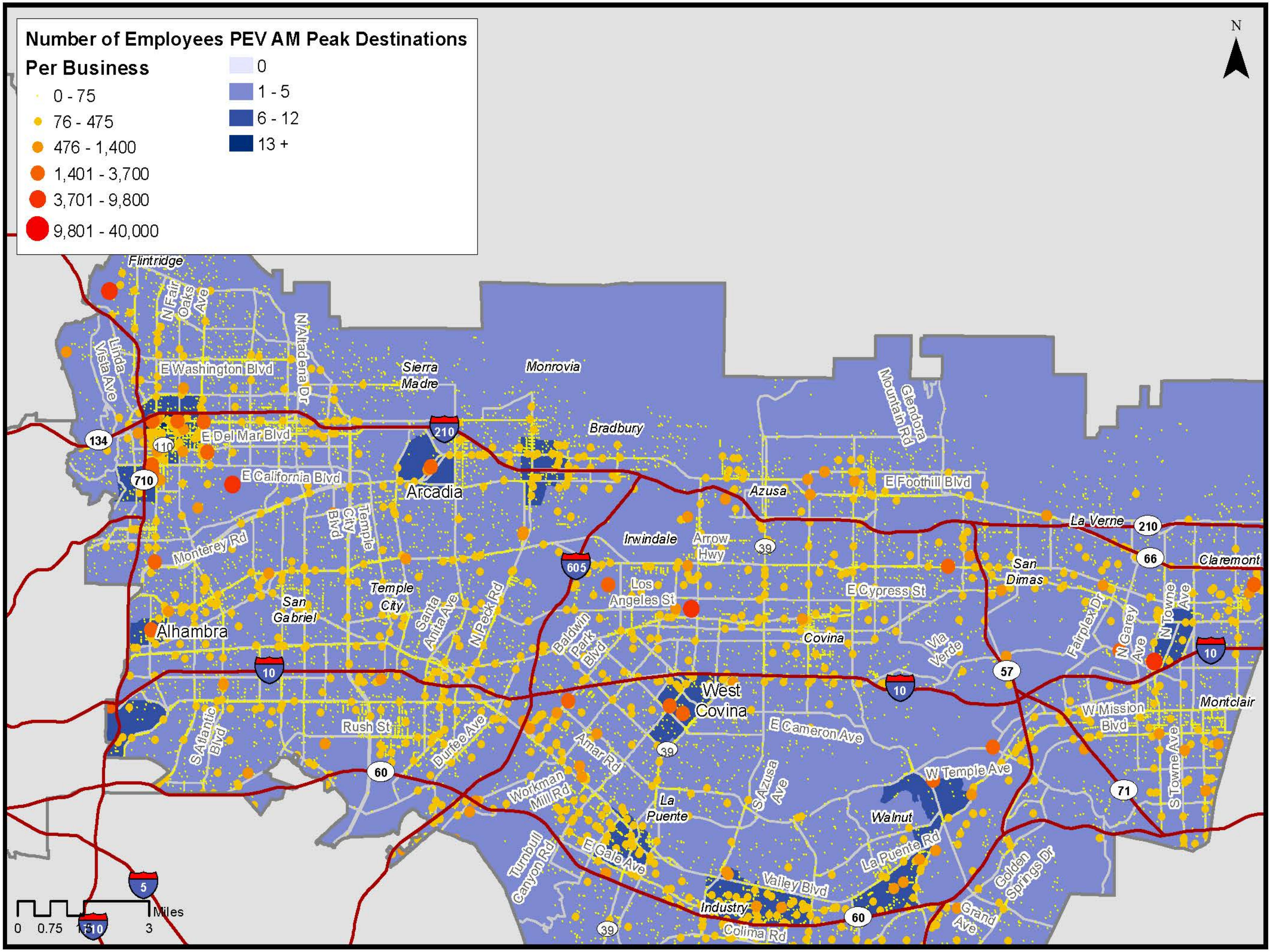
Understanding regional demand for charging

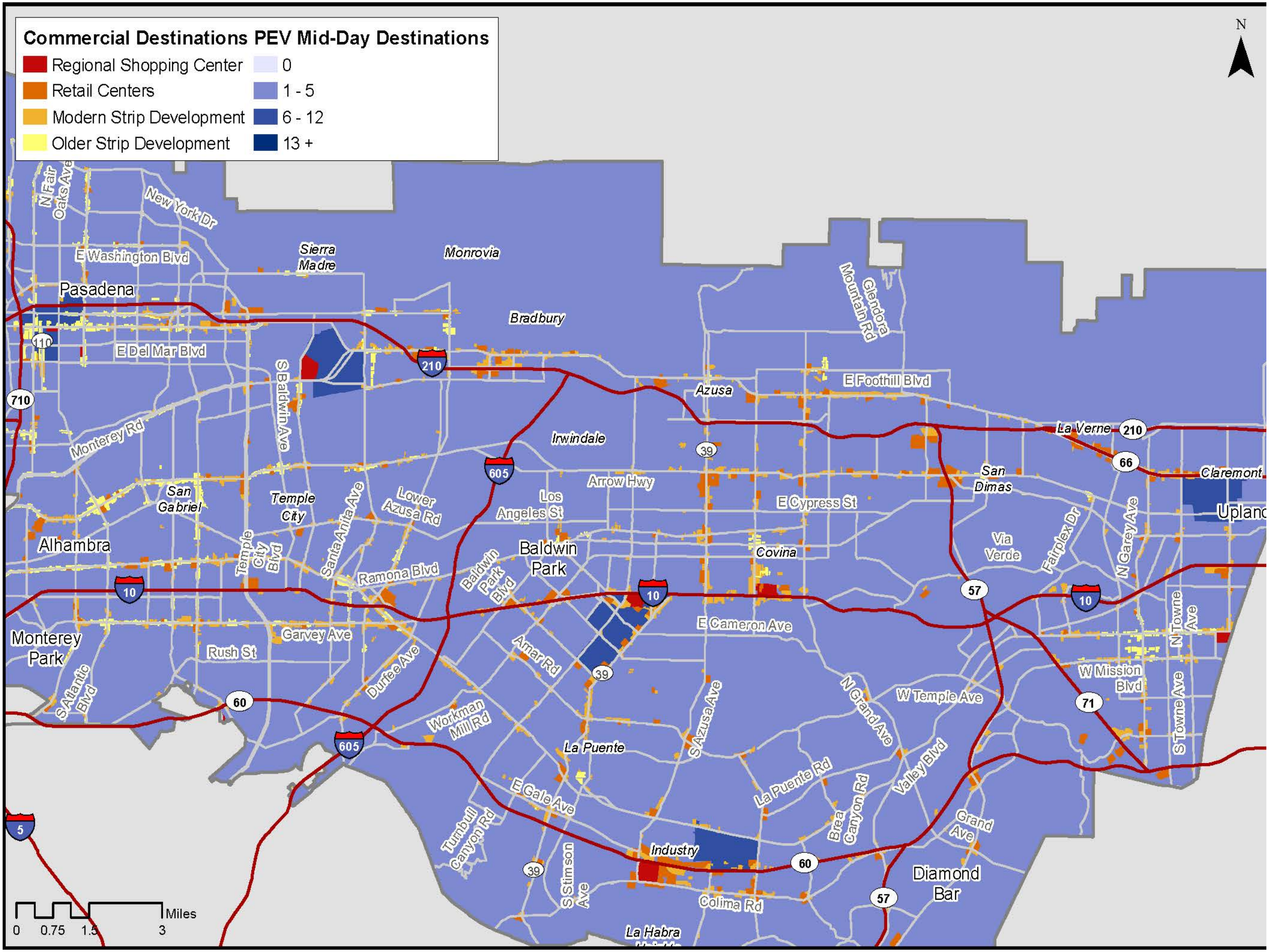
PEV densities and travel


PEV Registrations
0
1 - 5
6 - 12
13 +
N
La Cañada Flintridge
Linda Vista Ave
E Washington Blvd
Sierra Madre
Monrovia
Pasadena
Duarte
Bradbury
Glendora Mountain Rd
Glendora
Arcadia
Azusa
E Alosta Ave
San Marino
Irwindale
Arrow Hwy
La Verne
Claremont
South Pasadena
San Gabriel
Temple City
Santa Anita Ave
San Dimas
E Cypress St
N Towne Ave
Upland
Alhambra
Valley Blvd
Baldwin Park
El Monte
Via Verde
Fairplex Dr
N Garey Ave
Covina
Rosemead
West Covina
Pomona
Montclair
Monterey Park
S Atlantic Blvd
Montebello
W Mission Blvd
Rush St
South El Monte
Durfee Ave
Amar Rd
N Grand Ave
W Temple Ave
S Reservoir St
Workman Mill Rd
La Puente
S Azusa Ave
Walnut
Turnbull Canyon Rd
E Gale Ave
La Puente Rd
Golden Springs Dr
Diamond Bar
Industry
Grand Ave
Colima Rd
Miles
0 0.75 1.5 3

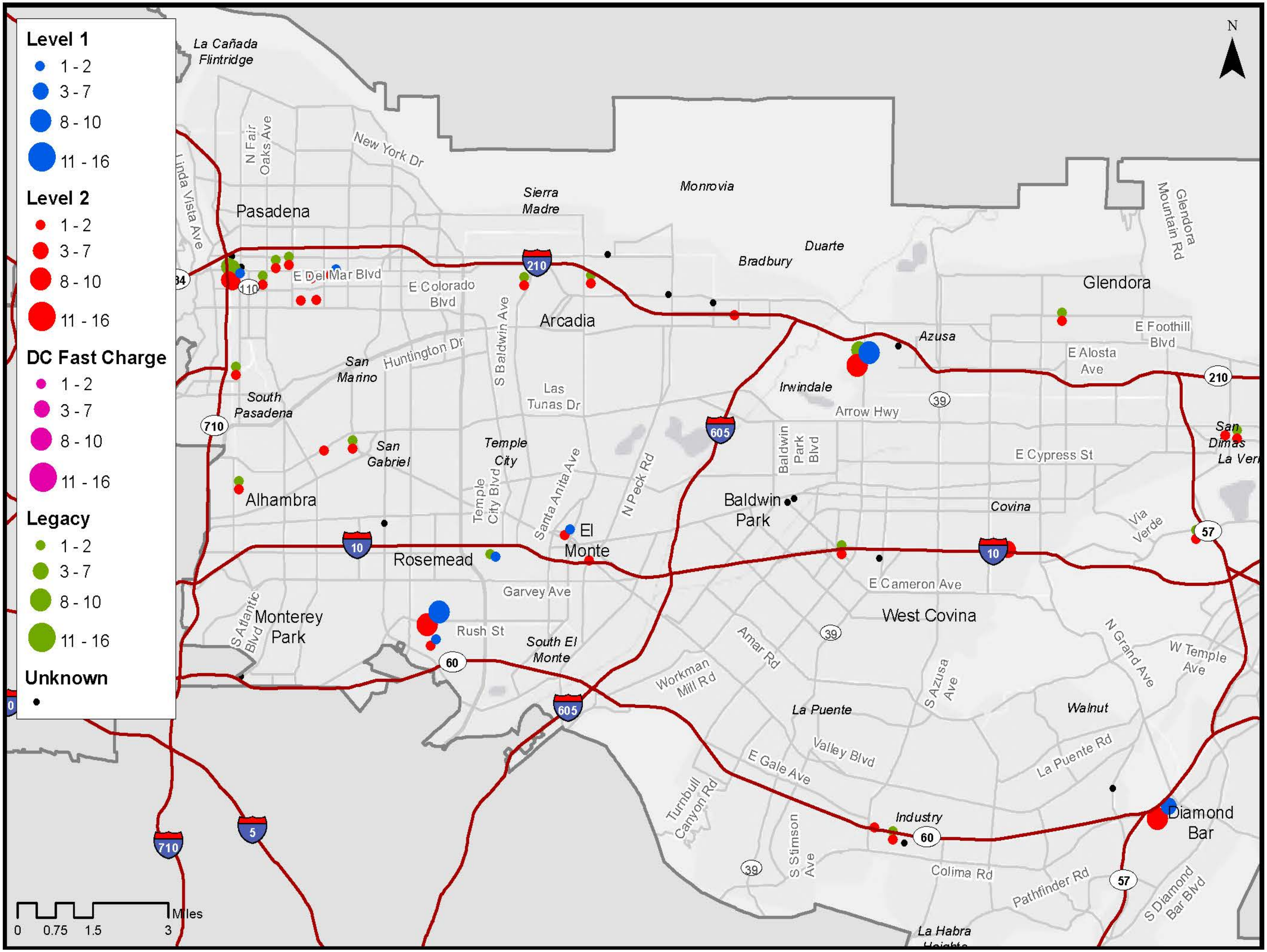

PEV AM Peak Destinations
0
1 - 5
6 - 12
13 +
N
Pasadena
Sierra Madre
Monrovia
Bradbury
Azusa
Irwindale
San Gabriel
Temple City
Alhambra
Baldwin Park
Covina
San Dimas
La Verne
Claremont
Upland
Via Verde
Monterey Park
La Puente
Industry
Diamond Bar
La Habra
Los Angeles St
E Washington Blvd
New York Dr
N Fair Oaks Ave
E Del Mar Blvd
S Baldwin Ave
Monterey Rd
E Foothill Blvd
Glendora Mountain Rd
Arrow Hwy
E Cypress St
Lower Azusa Rd
Santa Anita Ave
Temple City Blvd
Ramona Blvd
Baldwin Park Blvd
Fairplex Dr
N Garey Ave
N Towne Ave
E Cameron Ave
Garvey Ave
Rush St
Amar Rd
Durfee Ave
S Atlantic Blvd
Workman Mill Rd
W Mission Blvd
W Temple Ave
N Grand Ave
S Azusa Ave
S Towne Ave
La Puente Rd
Valley Blvd
E Gale Ave
Turnbull Canyon Rd
Brea Canyon Rd
Grand Ave
S Stimson Ave
Colima Rd
210
110
710
605
39
66
57
10
60
71
5
0
0.75
1.5
3
Miles



Number of Employees Per Business
0 - 75
76 - 475
476 - 1,400
1,401 - 3,700
3,701 - 9,800
9,801 - 40,000
PEV AM Peak Destinations
0
1 - 5
6 - 12
13 +
N
Flintridge
N Fair Oaks Ave
N Altadena Dr
Linda Vista Ave
E Washington Blvd
Sierra Madre
Monrovia
Glendora Mountain Rd
Bradbury
E Del Mar Blvd
E California Blvd
Arcadia
Azusa
E Foothill Blvd
La Verne
Claremont
Irwindale
Arrow Hwy
San Dimas
Monterey Rd
Temple City Blvd
Temple City
San Gabriel
Santa Anita Ave
N Peck Rd
Los Angeles St
E Cypress St
Alhambra
Baldwin Park Blvd
Covina
Via Verde
Fairplex Dr
N Garey Ave
N Towne Ave
West Covina
Montclair
W Mission Blvd
Rush St
S Atlantic Blvd
Durfee Ave
Amar Rd
E Cameron Ave
W Temple Ave
Workman Mill Rd
La Puente
S Azusa Ave
Walnut
S Towne Ave
E Gale Ave
Turnbull Canyon Rd
La Puente Rd
Golden Springs Dr
Valley Blvd
Industry
Colima Rd
Grand Ave
Miles
0 0.75 1.5 3



Commercial Destinations PEV Mid-Day Destinations
Regional Shopping Center
Retail Centers
Modern Strip Development
Older Strip Development
0
1 - 5
6 - 12
13 +
N
Pasadena
Sierra Madre
Monrovia
Bradbury
Azusa
Irwindale
La Verne
San Dimas
Claremont
Upland
San Gabriel
Temple City
Alhambra
Baldwin Park
Covina
Via Verde
Monterey Park
La Puente
Industry
Diamond Bar
La Habra Heights
E Washington Blvd
New York Dr
E Del Mar Blvd
Monterey Rd
S Baldwin Ave
E Foothill Blvd
Arrow Hwy
E Cypress St
Ramona Blvd
Garvey Ave
Rush St
E Cameron Ave
W Temple Ave
W Mission Blvd
Colima Rd
Miles
0
0.75
1.5
3


Level 1
1 - 2
3 - 7
8 - 10
11 - 16
Level 2
1 - 2
3 - 7
8 - 10
11 - 16
DC Fast Charge
1 - 2
3 - 7
8 - 10
11 - 16
Legacy
1 - 2
3 - 7
8 - 10
11 - 16
Unknown
N
Miles
0 0.75 1.5 3
La Cañada Flintridge
Pasadena
Sierra Madre
Monrovia
Duarte
Bradbury
Glendora
Arcadia
Azusa
Irwindale
San Marino
South Pasadena
San Gabriel
Temple City
Alhambra
Rosemead
El Monte
Baldwin Park
Covina
San Dimas
Monterey Park
South El Monte
West Covina
La Puente
Walnut
Industry
Diamond Bar
La Habra Heights
New York Dr
N Fair Oaks Ave
Linda Vista Ave
E Del Mar Blvd
E Colorado Blvd
Huntington Dr
S Baldwin Ave
Las Tunas Dr
Arrow Hwy
E Foothill Blvd
E Alosta Ave
Glendora Mountain Rd
Baldwin Park Blvd
E Cypress St
Temple City Blvd
Santa Anita Ave
N Peck Rd
Via Verde
Garvey Ave
Rush St
S Atlantic Blvd
E Cameron Ave
Amar Rd
N Grand Ave
W Temple Ave
Workman Mill Rd
S Azusa Ave
Valley Blvd
E Gale Ave
La Puente Rd
Turnbull Canyon Rd
S Stimson Ave
Colima Rd
Pathfinder Rd
S Diamond Bar Blvd
210
110
710
605
39
10
57
60
5

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Understanding a region's potential charging supply

Hosting capacity by type

Potential Charging Supply: South Bay Cities Example

	Employee Count	Rank	% Employee	Rank	Multi-Family Count	% Multi-Family	Single-Family Count	% Single-Family
Torrance	114,489	1	68%	4	24,343	15%	28,482	17%
Carson	75,483	2	76%	2	5,634	6%	17,928	18%
Inglewood	42,231	3	55%	6	22,626	30%	11,448	15%
Gardena	34,307	4	65%	5	10,011	19%	8,329	16%
El Segundo	30,799	5	82%	1	4,071	11%	2,587	7%
Hawthorne	24,791	6	48%	9	20,260	39%	6,653	13%
Redondo Beach	23,084	7	46%	10	18,888	37%	8,485	17%
Manhattan Beach	16,582	8	53%	7	4,654	15%	9,793	32%
Lawndale	7,599	9	50%	8	5,467	36%	2,112	14%
Hermosa Beach	7,419	10	45%	11	5,700	35%	3,289	20%
Rolling Hills Estates	6,416	11	69%	3	127	1%	2,727	29%
Rancho Palos Verdes	5,942	12	27%	14	3,247	15%	12,573	58%
Lomita	5,341	13	40%	12	4,981	37%	2,966	22%
Palos Verdes Estates	2,052	14	27%	13	349	5%	5,095	68%

Torrance Workplace-Charging Example

PEV Density	
High (H)	3
Moderate (M)	2
Other	0

Own/Lease	
Owned (O)	1
Leased (L)	0
Unknown (U)	0

High Tech	
Yes (Y)	1
No (N)	0

White Collar	
50% of more	1
Less than 50%	0

Torrance

	Company	Address	City	ST	ZIP	Type	Employees	PEV	Points	Own/Lease	Point	High Tech	Points	Wht Collar	Points	Total Points
1	Little Company of Mary Hosp	4101 Torrance Blvd	Torrance	CA	90503	Hospitals	3,500	M	2	U	0	N	0	88	1	3
2	Westbay Water Co	1606 Crenshaw Blvd	Torrance	CA	90501	Water Companies-Bottled, Bulk, Etc	2,500	M	2		0	N	0	71	1	3
3	Torrance City Hall	3031 Torrance Blvd	Torrance	CA	90503	City Government-Executive Offices	2,000	M	2	O	1	N	0	0	0	3
4	Alcoa Fastening Systems	3000 Lomita Blvd	Torrance	CA	90505	Fasteners-Industrial (Wholesale)	1,500	M	2	U	0	N	0	73	1	3
5	Motorcar Parts of America Inc	2929 California St	Torrance	CA	90503	Alternators & Generators-Automotive-Mfrs	833	M	2	L	0	N	0	27	0	2
6	Virco Mfg Corp	2027 Harpers Way	Torrance	CA	90501	Furniture-Manufacturers	800	H	3	U	0	N	0	27	0	3
7	Real Estate Group-Escrow	3480 Torrance Blvd	Torrance	CA	90503	Real Estate	650		0		0	N	0	70	1	1
8	L-3 Electron Technologies Inc	3100 Lomita Blvd	Torrance	CA	90505	Aerospace Industries (Mfrs)	600	H	3		0	Y	1	79	1	5
9	Robinson Helicopter Co Inc	2901 Airport Dr	Torrance	CA	90505	Aircraft-Manufacturers	600	H	3	O	1	Y	1	52	1	6
10	Lisi Aerospace Hi-Shear Corp	2600 Skypark Dr	Torrance	CA	90505	Automobile Parts & Supplies-Mfrs	500	H	3	O	1	N	0	26	0	4

Total Points
4
5
6

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Pricing Workplace Charging: Financial Viability and Fueling Costs

Brett Williams, MPhil (cantab), PhD and JR DeShazo, PhD

Transportation Research Record (forthcoming)

Workplace Charging Financial Viability: Abstract

Two perspectives assessed:

1) employers investing in facilities and pricing their use
2) employee drivers.

- Pricing levels that motivate drivers to "fuel" at work may provide limited station cost recovery.
- $1.25/hour, $0.20/kWh markup on electricity, or $35/month each cover only ~$1,500 in all-in facility costs per PEV.
- Monte Carlo simulation highlights key assumptions, indicates employers' choice of pricing structure affects viability in the face of uncertainty.
- "Multiplexed," perhaps lower-power charging might help.
- The differential, "discriminatory" impact of different pricing structures on different drivers is also discussed.

Station profitability

10-year present value of net revenues
(NPV)

Workplace charging breakeven pricing: per-hour

Cost of fueling

Table 3-7: Illustrative fueling cost benchmarks: Per-hour workplace charging

Pricing Level	$ per electric mile	Electricity equivalent	Gasoline equivalent (CV)	Gasoline equivalent (PHEV)
H1. $0.50/hour actively charging	$0.05/e-mi	$0.14/kWh	$1.34/gal	$2.02/gal
H2. $0.75/hour actively charging	$0.07/e-mi	$0.21/kWh	$2.01/gal	$3.03/gal
H3. $1.25/hour actively charging	$0.12/e-mi	$0.36/kWh	$3.35/gal	$5.05/gal

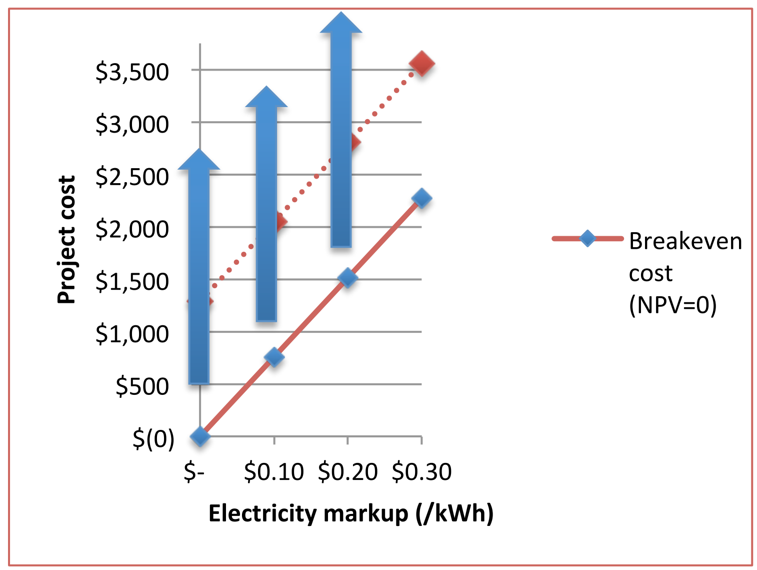
Supplemental Value?

- Given the limited cost-recovery potential of workplace charging, some employers may want additional value
- Might secondary use of charging facilities help?
  - Employee + fleet + nighttime public access?
  - Control (and aggregation) of recharging timing and rate (i.e., smart charging) to provide grid-support services

Grid-support revenue streams

Application	PHV	Volt	LEAF
Electric Energy Time-shift	$330	$880	$1,720
Electric Supply Capacity	$320	$850	$1,670
Load Following	[illegible]	$2,130	$4,180
Area Regulation	[illegible]	$23,250	[illegible]
Electric Supply Reserve Capacity	$280	[illegible]	[illegible]
Voltage Support	$2,870	[illegible]	$15,040
Transmission Support	[illegible]	[illegible]	$6,270
Transmission Congestion Relief	[illegible]	$150	$300
T&D Upgrade Deferral 50th percentile†	$2,390	$6,470	$12,490
T&D Upgrade Deferral 90th percentile†	$3,760	$10,020	$19,660
Substation On-site Power	$600	$1,600	$3,130
Time-of-use Energy Cost Management	$730	$1,960	$3,840
Demand Charge Management	$220	$580	$1,140
Electric Service Reliability	$3,700	$9,860	$19,340
Electric Service Power Quality	$4,170	$11,120	$21,820
Renewables Energy Time-shift	$230	$620	$1,220
Renewables Capacity Firming	$810	$2,160	$4,240
Wind Generation Grid Integration, Short Duration	$4,680	$12,480	$24,480
Wind Generation Grid Integration, Long Duration	$380	$1,000	$1,970

lifecycle benefit over 10 years, with 2.5% escalation and 10% discount rate
† converted here to approximate 10 years of benefit to be comparable to other applications, but this is not likely at a single location



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Avoiding zero-sum-game dynamics

Mercedes plug-in F-125 FCEV prototype

- No clear “winner” for all applications
- Consider batteries as storage in the context of hybrid platform evolution
  - What degree of hybridization can you afford and use?
  - If 100% (i.e., BEV) gets the job done, look no further
  - If not (for whatever combination of reasons), hybrid platforms will need a clean, efficient potential replacement for combustion engines
  - Electrochemistries of the future blur the lines anyway

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Thank you for your attention!

Additional slides, references available…

Acknowledgements and Additional Sources

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- hybridcars.com for most of the PEV sales data
- RL Polk & Co., supplier of CA registration data bought for UCLA Luskin EV Initiative research

Some terms (others defined within)

AB	assembly bill
AQMD	air quality management district
CA	California
CARB	California Air Resources Board
CEC	California Energy Commission
CO_2e	carbon-dioxide-equivalent (greenhouse-gas emissions)
EPA	Environmental Protection Agency
EV	electric-drive vehicle (hybrid, plug-in-hybrid, all-battery and fuel-cell EVs)
GHG	greenhouse gas
NHTSA	National Highway Traffic Safety Administration
ZEV	zero-tailpipe-emission vehicle (plug-in and fuel-cell EVs)

Notes about these slides

- EV = electric-drive vehicle = conventional hybrids + PEVs + FCEVs
  - HEVs = hybrid EVs (aka "hybrids") = conventional (all-gasoline) hybrids + PHEVs
  - PEVs = plug-in electric vehicles (aka "plug-ins") = BEVs + PHEVs
    - PHEVs = plug-in hybrid EVs (aka "plug-in hybrids")
    - BEVs = all-battery EVs (aka "all-electric")
  - FCEVs = fuel-cell EVs
- Figure legend order usually reflects sequence of vehicle introduction.
- No single source used contained a complete and/or accurate list of sales data, so multiple sources were compiled by the National Renewable Energy Laboratory (gasoline-only hybrid data), CNCDA (California yearly totals), and UCLA Luskin Center (PEV data, most of which were compiled from monthly reports at hybridcars.com).
- Data for the Tesla Roadster, Cooper MINI-E, Th!nk City, Azure Transit Connect Electric, Fisker Karma, and Coda Sedan are usually not included.
- Tesla Model S sales are estimates and increasingly overestimate U.S. sales as the vehicle is marketed globally. Further, for simplification, it is assumed that all 2012 sales are the 85kWh model and 2013 and subsequent sales are the 60kWh model.

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